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REPORT NO. 46

STUDY OF PRESSURES RECORDED ON COPPER CRUSHER CYLINDERS WHEN USED FOR MORE THAN ONE ROUND

by

R. C. Gerdom

April 1936

U.S. ARMY ABERDEEN RESEARCH AND DEVELOPMENT CENTER
BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND

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ABERDEEN PROVING GROUND
MARYLAND

BALLISTIC RESEARCH LABORATORY
REPORT

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R. C. GERDOM

[redacted]

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7 APRIL 1936
ORDNANCE RESEARCH CENTER
PROJECT NO._____

Report No. 46

RCG/emh
Aberdeen Proving Ground, Md.
April 7, 1936

STUDY OF PRESSURES RECORDED ON COPPER CRUSHER CYLINDERS WHEN USED FOR MORE THAN ONE ROUND

(In Connection with Project RB 116).

Abstract

Records of pressures were obtained by using the same copper crusher cylinders for several rounds. These were compared with the pressures obtained by the usual method during the firing of pressure rounds in the 105 mm, 12" and 14" guns.

Introduction

The Coast Artillery, when engaged in target practice, takes pressures on each trial shot. During the record series, however, time does not permit the removal and replacement of gauges each round. They, therefore, leave major caliber gauges containing copper crusher cylinders in the gun during the series and assume the pressure recorded on these coppers is the maximum pressure occurring during the series.

It is the purpose of this test to evaluate the errors resulting from this assumption.

Procedure

Additional gauges containing test coppers were inserted in pressure round as follows:

Gun	No. of Rds.	No. of Gauges Med. Cal.	Major Cal.
12"	1	2	1
14"	17	9	1
105 mm A.A.	27	2	

With one exception, gauges containing test coppers were disassembled and the coppers measured each time they were subjected to a pressure. Gauge containing copper No. 19 was disassembled after being inserted in seventeen rounds of the 14" gun, at which time, it was found that gas had leaked by the obturating washer.

The lengths of the compressed coppers were measured to the nearest thousandth of an inch. Irregularities of the faces of compressed coppers and the lack of time between rounds made greater precision impossible.

Results

The results of the pressure measurements are given in Table I.

The results recorded during the firing of the 12 and 14" guns were quite different from those recorded during the firing of the 105 mm gun. Therefore two sets of plots were made: Plot No. 1 and Plot No. 2 cover the firing of the 12" and 14" gun and Plot 3 and 4 cover the firing of the 105 mm gun.

In plots Nos. 1, 2, 3 and 4

Δp_t vs $(p_{ti} - p_m)$ are plotted. The symbols are defined as follows:

Symbol	Definition
Δp_t	Increase in pressure for any one round as recorded on test copper.
p_{ti}	Pressure previously recorded on test copper.
p_m	Mean pressure recorded on uncompressed coppers.

In plots 2 and 4, only positive values of $p_{ti} - p_m$ are used.

Discussion

From plots No. 1 and No. 2 it appears that when loose medium caliber gauges, having the present prescribed piston clearances are used in 12" and 14" guns which have approximately 0.02 seconds pressure duration and subjecting them to a pressure not exceeding 34,000 lb/in^2;

a. Precompressed coppers may be subjected to any number of pressures, providing such pressures be at least 2500 lb/in^2 less than the previously applied pressure, without showing additional compression.

b. That precompressed coppers, when subjected to pressures of from 0 - 2500 lb/in^2 less than the previously applied pressure may record pressures 1000 lb/in^2 greater than the maximum pressure to which they had been previously subjected.

c. That precompressed coppers, when subjected to pressures greater than the previously applied pressure, may record pressures as great as 5000 lb/in^2 in excess of the pressures to which they have been subjected as measured by uncompressed coppers.

From plots No. 3 and No. 4 it appears that when loose medium caliber gauges, having the present prescribed piston clearances are used in 105 mm guns which have approximately .01 sec. pressure duration and exposing them to a pressure not exceeding 44,000 lb/in^2;

a. Additional compression of previously compressed coppers may take place even when the subsequent pressure is 7000 lb/in^2 less than the pressures previously recorded.

The difference of these results as compared with those recorded during the 12 and 14" gun firings may be explained by the difference in the time of exposure to pressure.

Attention is invited to the peculiar results obtained during the firing of the 105 mm gun as shown on plot 3. Here we find that when the pressure applied to the test coppers is greater than the pressure previously applied, the pressure recorded by the test coppers may be 4000 lb/in^2 less than the pressure recorded by uncompressed coppers.

The following explanation is offered for these results. When uncompressed coppers are used in guns such as the 105 mm in which a rapid rise in pressure takes place, the pistons in the gauge have a greater velocity than when partially compressed coppers are used. Likewise the friction of both the piston and obturating cups would be less with uncompressed coppers since they would start moving at a relatively low pressure. These conditions would tend to result in over shooting when uncompressed coppers are used. Under such conditions uncompressed coppers might record higher pressures than would partially compressed coppers.

Obviously the two records which show approximately double this amount of difference cannot be explained by the above conditions. It is thought these may be explained by pinching of the pistons.

It should be stated most emphatically that the pressure relations given in the preceding are only approximate. The probable error of the reading of the single gauge is of the order of magnitude of 1000 lb/in^2. Hence the values given in the preceding paragraph have large probable errors.

Major caliber gauges, only, are used for more than one round by the Coast Artillery. Since the results presented in this report were obtained principally by the use of medium caliber gauges, the dispersions are probably much greater than if major caliber gauges having adequate piston clearances had been used.

From report entitled "Report on Some Sources of Error in Piezo-Electric and Crusher Gauge Measurements" by R. H. Kent, it is evident that with the present piston clearances, pinching of the pistons should begin at relatively low pressures.

This inference is confirmed by recent tests during which comparative data of the effect of various piston clearances were obtained. See "Report on Investigation of the Cause Underlying Erratic Powder Pressures Obtained by Crusher Gauges" by Captain T. K. Vincent.

In view of these facts, it is thought probable that when gauges having properly designed clearances are obtainable, this test might be repeated and results having a much greater degree of accuracy obtained.

The undersigned is much indebted to Mr. R. H. Kent for advice and consultation.

R. C. Gerdom.

H. H. Zornig,
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Chief Research Division

TABLE NO. I

TABULATION OF RESULTS OBTAINED DURING TEST

Date	Gun	Rd. No.	Mean Indicated Press, lb/in^2	Major Gauge Press, lb/in^2	Med. Gauge Press, lb/in^2	Med. Gauge Press, lb/in^2	Med. Gauge Press, lb/in^2	Test Copper No. 1, lb/in^2	Test Copper No. 2, lb/in^2
10/24/35	105 mm	1	25,700		25,950	25,470		25,800	25,800
	Tube No.	2	36,800		37,600	36,000		34,500	34,700
	6222	3	33,250		34,850	31,650		34,850	34,850
	P13	4	44,000		44,750	43,250		40,400	35,500
		5	37,700		38,900	36,550		40,400	35,500
10/29/35	12" Gun	1	21,400	21,300	21,450	21,450			
	1888 M2								
	No. 29								
11/4/35	14" D.C.	1	11,950	11,150	12,250	12,450		40,400	35,500
	Mod.	2	14,700	14,500	14,700	14,900		40,400	35,500
	1910	3	19,950	20,100	20,450	19,250		40,400	Skid
	No. 18	4	26,450	30,100	29,500	19,600		40,400	
		5	28,850	29,050	28,600	28,900		40,400	
		6	34,200	38,350	29,800	34,500		40,400	
		7	25,950	31,800	26,400	19,600		40,400	
11/11/35	14" D.C.	1	11,250	10,700	11,600	11,400		40,400	
	Mod.	2	30,450	31,025	31,025	28,700	31,025	40,400	
	1910	3	31,550	33,350	30,550	32,300	29,950	40,400	
	No. 18	4	31,700	30,900	33,050	31,350	31,500	40,400	
		5	28,300	30,300	28,700	28,450	25,800	40,400	
		6	28,000	30,400	29,800	26,700	25,150	40,550	
		7	31,500	32,300	31,500	30,700	Skid	40,550	
		8	30,850	32,300	30,300	30,700	30,100	40,550	
		9	31,350	32,600	32,600	28,900	Skid	40,550	
		10	31,050	31,500	31,350	30,250		40,550	
11/14/35	105 mm	1	37,800		37,250	38,350			
	M1 No. 1								
11/15/35	M1 No. 7	3	38,300		38,100	38,500			
	105 mm	4	37,700		40,400	35,000			
	M3	5	38,600		35,650	41,500	- - - -	41,300	
		6	39,700		39,250	40,200			
		7	39,350		39,250	39,450			
		8	41,300		40,950	41,700			
		9	41,200		41,900	40,550			
		10	41,700		41,300	42,100			
		11	40,600		40,200	40,950	- - - -	41,300	
		12	40,800		40,550	40,950			
		13	41,100		40,950	41,300			
		14	40,100		39,800	40,400			
		15	37,500		38,500	36,550			
		16	38,900		38,700	39,050	- - - -	41,900	
		17	38,200		37,450	38,900			
		18	40,000		39,050	40,950			
		19	34,100		37,100	31,050			
		20	36,050		37,250	34,850			
		21	35,950		32,100	39,800			
		22	37,550		37,100	38,000	- - - -	42,300	
		23	38,100		38,000	38,150			

TABLE NO. I

TABULATION OF RESULTS OBTAINED DURING TEST

Date	Gun	Rd. No.	Mean Indicated Press. lb/in^2	Test Copper No. 3, lb/in^2	Test Copper No. 4 lb/in^2	Test Copper No. 5 lb/in^2	Test Copper No. 6 lb/in^2	Test Copper No. 7 lb/in^2	Test Copper No. 8 lb/in^2
10/24/35	105 mm	1	25,700						
	Tube No.	2	36,800						
	6222	3	33,250						
	P13	4	44,000						
		5	37,700						
10/29/35	12" Gun	1	21,400	19,800	19,100	19,600			
	1868 22								
	No. 29								
11/4/35	14" D. C.	1	11,950		19,100	19,600	11,900		11,400
	Model	2	14,700		19,100	19,600	14,500		14,500
	1910	3	19,950		21,100	20,800	19,450		20,950
	No. 18	4	26,450		31,050	30,250	31,650		31,200
		5	26,650	31,200	31,350	30,700	31,650		31,200
		6	34,200	37,250	35,500	37,100	33,350		31,200
		7	25,950	37,250	35,500				
11/11/35	"	1	11,250	37,250	35,500				
		2	30,450	37,250	35,500				
		3	31,550	37,450	35,500				
		4	31,700	37,450	35,500				
		5	28,300	37,450	35,500				
		6	28,000	37,450	35,500				
		7	31,500	37,450	35,500				
		8	30,650	37,450	35,500				
		9	31,350	37,450	35,700				
		10	31,050	37,450	35,700				
11/14/35	105 mm	1	37,800						
	1 No. 1								
11/15/35	1 No. 7	3	38,800						
	105 mm	4	37,700						
	M3	5	38,600						41,800
		6	39,700	38,450					
		7	39,350		39,100				
		8	41,300						
		9	41,800						
		10	41,700		40,400				
		11	40,600						41,300
		12	40,800						
		13	41,100	39,400					
		14	40,100	40,400					
		15	37,500		40,950				
		16	38,900						41,700
		17	38,200						
		18	40,000						
		19	34,100		41,100				
		20	36,050						
		21	35,950	41,500					
		22	37,550						41,900
		23	38,100						

TABLE NO. I

TABULATION OF RESULTS OBTAINED DURING TEST

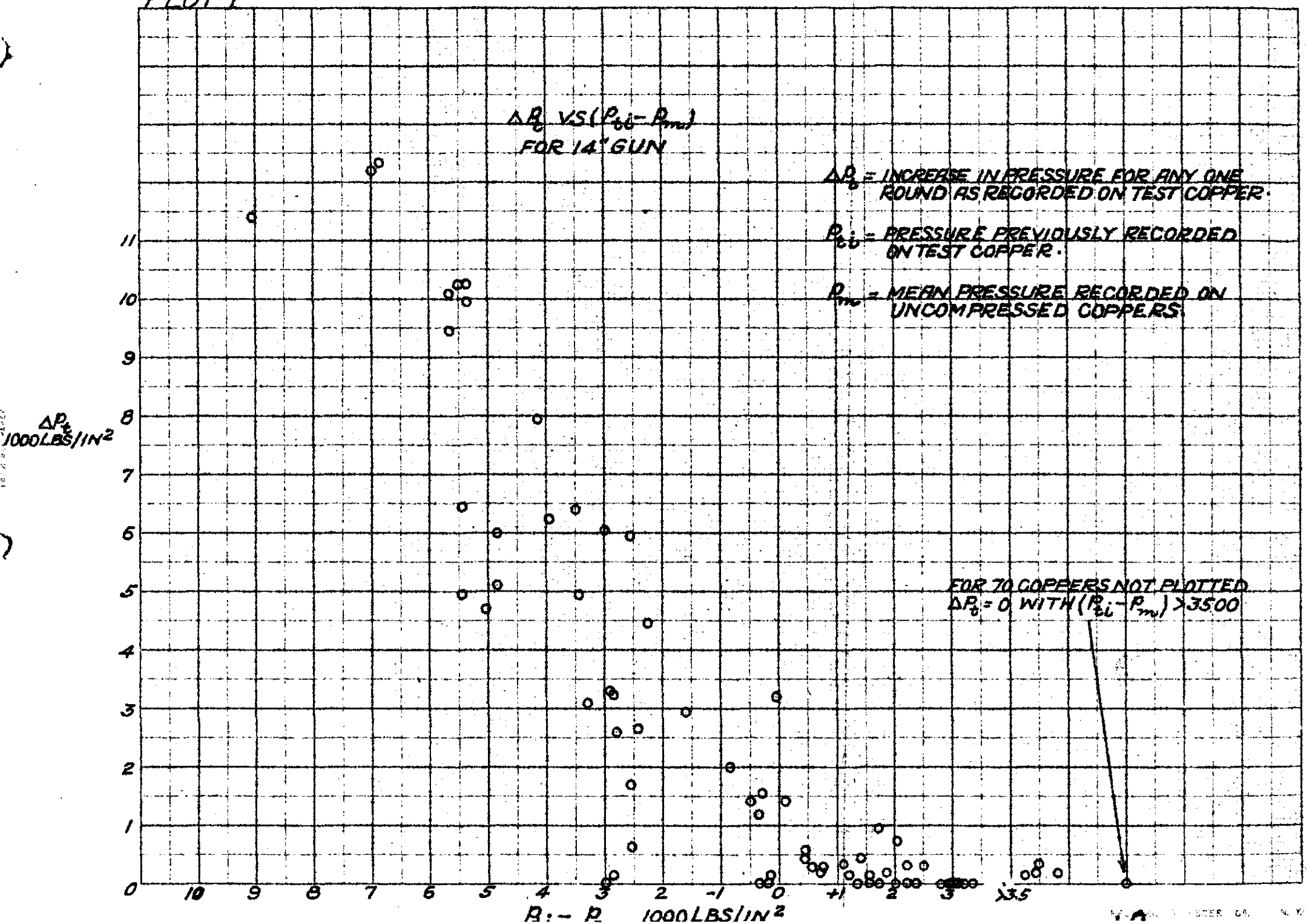
Date	Gun	Rd. No.	Mean Indicated Press, lb/in^2	Test Copper No. 15 lb/in^2	Test Copper No. 16 lb/in^2	Test Copper No. 17 lb/in^2	Test Copper No. 18 lb/in^2	Test Copper No. 19 lb/in^2	Test Copper No. 20 lb/in^2
10/24/35	105 mm Tube No. 6222 P13	1	25,700						
		2	36,800						
		3	33,250						
		4	44,000						
		5	37,700						
10/29/35	12" Gun 1888 M2 No. 29	1	21,400						
11/4/35	14" D.C. Mod.1910 No. 18	1	11,950						
		2	14,700						
		3	19,950						
		4	26,450						
		5	28,850						
		6	34,200						
		7	25,950	30,900	29,950	30,700		Not disassembled between rounds	
11/11/35	14" D.C. Model 1910 No. 18	1	11,250	- - - - - - - - - - - - - - - - - -					10,700
		2	30,450	31,500	31,350		32,100		28,100
		3	31,550	34,700	31,350		32,400		33,050
		4	31,700	34,700	31,350		32,600		33,050
		5	26,300	34,700	31,350		32,600		33,050
		6	28,000	34,700	31,350		32,600		33,050
		7	31,500	34,700	31,500		33,050		33,200
		8	30,650	34,700	31,800		33,050	Leak	33,200
		9	31,350	34,700	32,250		34,000	Under	33,400
		10	31,050	34,700	32,400		34,000	Head	33,400
11/14/35	105 mm M1 No. 1	1	37,800	37,300	- - - - - - - - -		34,000		
11/15/35	M1 No. 7 105 mm M3	3	38,300	37,300	- - - - - - - - -		36,700		
		4	37,700	38,900	- - - - - - - - -		39,250		
		5	38,600						
		6	39,700						
		7	39,350						
		8	41,300		32,600				
		9	41,200	39,100	- - - - - - - - -		39,400		
		10	41,700						
		11	40,600						
		12	40,800		38,000				
		13	41,100						
		14	40,100						
		15	37,500						
		16	38,900						
		17	38,200	40,600			41,300		
		18	40,000		38,300				
		19	34,100						
		20	36,050	40,800			41,300		
		21	35,950						
		22	37,550						
		23	38,100		39,600				

TABLE NO. I

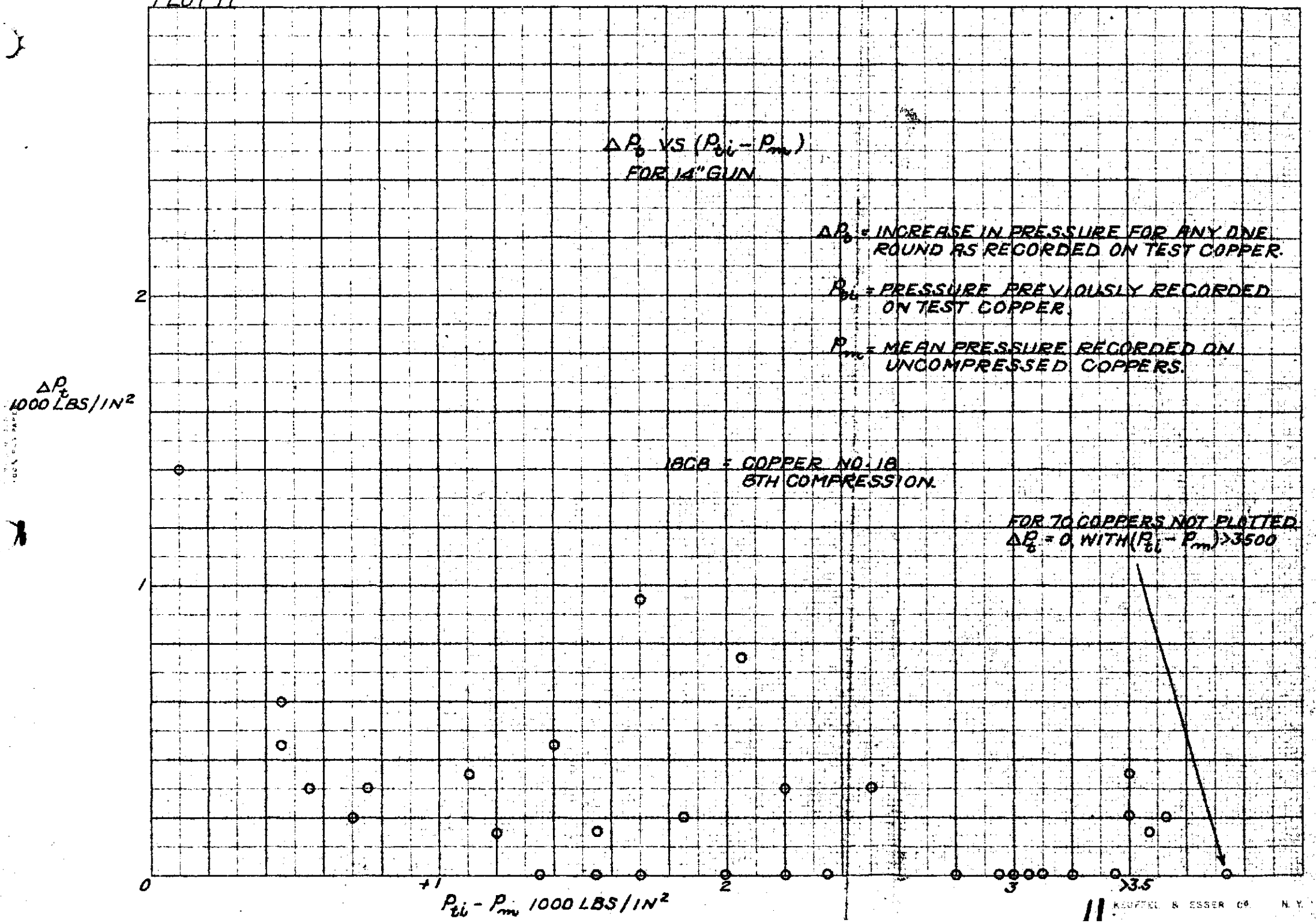
TABULATION OF RESULTS OBTAINED DURING TEST

Date	Gun	Rd. No.	Mean Indicated Press. lb/in^2	Test Copper No. 9 lb/in^2	Test Copper No. 10 lb/in^2	Test Copper No. 11 lb/in^2	Test Copper No. 12 lb/in^2	Test Copper No. 13 lb/in^2	Test Copper No. 14 lb/in^2
10/24/35	105 mm Tube No. 6222 P13	1	25,700						
		2	36,800						
		3	33,250						
		4	44,000						
		5	37,700						
10/29/35	12" Gun 1888 M2 No. 29	1	21,400						
11/4/35	14" D.C. Model 1910 No. 18	1	11,950	11,850	12,250	11,800	13,100		
		2	14,700	15,100	14,900	15,100	16,050		
		3	19,950	21,100	19,600	20,800	22,300		
		4	26,450	31,350	31,950	30,900	30,250		
		5	28,850	31,650	31,950	31,650	Skid		
		6	34,200	37,600	36,400	38,150		38,900	
		7	25,950	37,600	36,400			38,900	30,100
11/11/35	14" D.C. Model 1910 No. 18	1	11,250	37,600					
		2	30,450	37,600	36,400	- - - - - - - - - - - -			31,650
		3	31,550	37,600	36,400	- - - - - - -	- - - - - -		33,050
		4	31,700	37,600	36,400	- - - - - - - - - - - -			33,050
		5	28,300	37,600	36,400	- - - - - - - - - - - -			33,050
		6	28,000	37,950	36,400	- - - - - - - - - - - -			33,050
		7	31,500	37,950	36,400	- - - - - - - - - - - -			33,050
		8	30,850	37,950	36,400	- - - - - - - - - - - -			33,050
		9	31,350	37,950	36,400	- - - - - - - - - - - -			33,050
		10	31,050	37,950	36,400	- - - - - - - - - - - -			33,050
11/14/35	105 mm M1 No. 1	1	37,800						
11/15/35	M1 No. 7 105 mm M3	3	36,300						
		4	37,700						
		5	38,500						
		6	39,700		39,600				
		7	39,350	39,100					
		8	41,300	- - - - - - - - - - - - - - - - - - - -					37,300
		9	41,200						
		10	41,700	39,800					
		11	40,600						
		12	40,800	- - - - - - - - - - - - - - - - - - - -					37,300
		13	41,100	- - -	40,200				
		14	40,100	- - - -	40,400				
		15	37,500	40,200					
		16	38,900						
		17	36,200						
		18	40,000	- - - - - - - - - - - - - - - - - - - -					39,600
		19	34,100	40,600					
		20	36,050						
		21	35,950	- - - -	40,600				
		22	37,550						
		23	38,100	- - - - - - - - - - - - - - - - - - - -					40,000

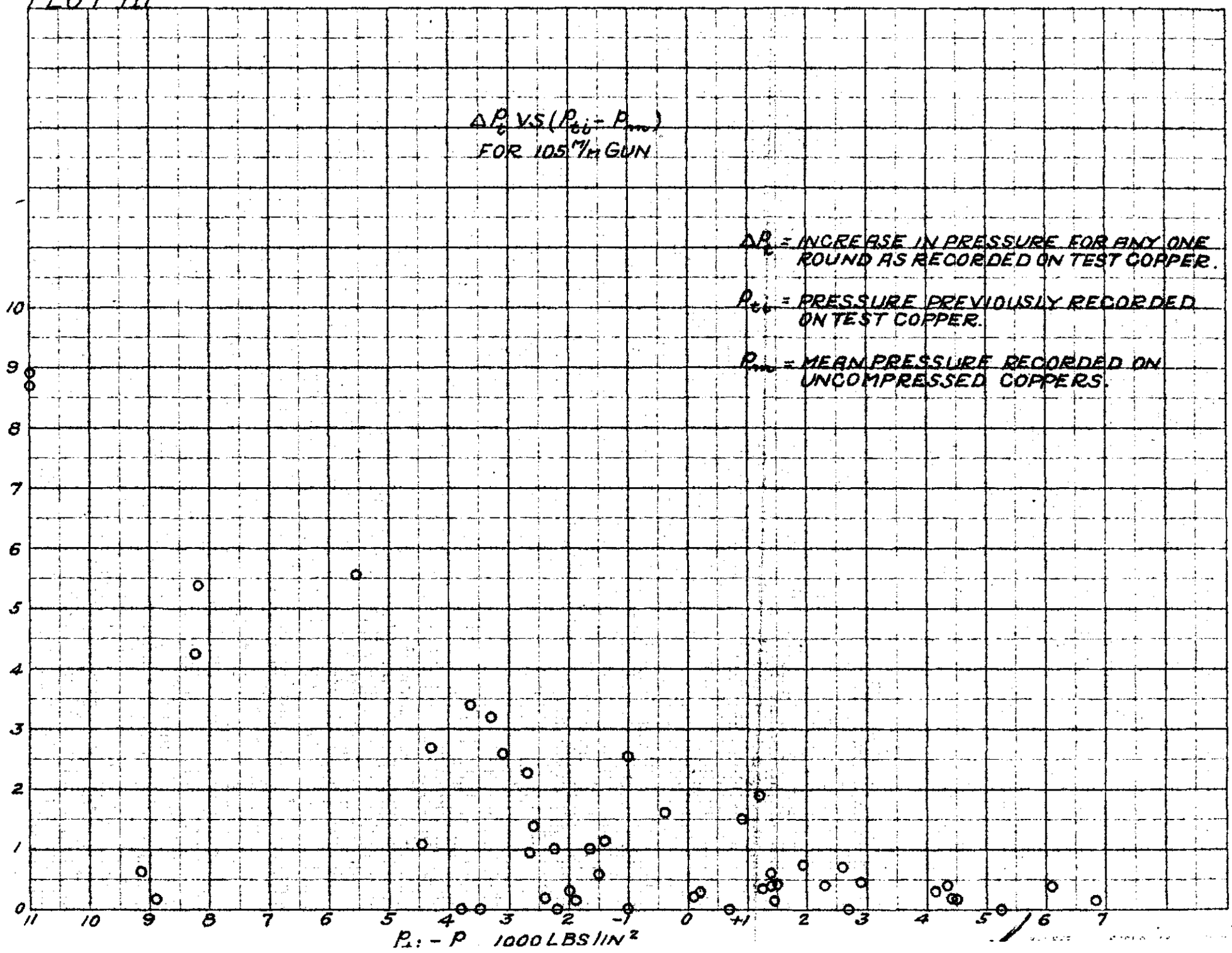
PLOT I


ΔP_t VS (P_tL - P_mL)
FOR 14" GUN
ΔP_t = INCREASE IN PRESSURE FOR ANY ONE ROUND AS RECORDED ON TEST COPPER.
P_tL = PRESSURE PREVIOUSLY RECORDED ON TEST COPPER.
P_mL = MEAN PRESSURE RECORDED ON UNCOMPRESSED COPPERS.
FOR 70 COPPERS NOT PLOTTED ΔP_t = 0 WITH (P_tL - P_mL) > 3500
ΔP_t 1000 LBS/IN²
11
10
9
8
7
6
5
4
3
2
1
0
10
9
8
7
6
5
4
3
2
-1
0
+1
2
3
>3.5
P_t - P_m 1000 LBS/IN²

PLOT II



PLOT III


ΔP_t V.S $(P_{ti} - P_m)$
FOR 105 M/M GUN
ΔP_t = INCREASE IN PRESSURE FOR ANY ONE ROUND AS RECORDED ON TEST COPPER.
P_{ti} = PRESSURE PREVIOUSLY RECORDED ON TEST COPPER.
P_m = MEAN PRESSURE RECORDED ON UNCOMPRESSED COPPERS.
ΔP_t 1000 LBS/IN²
0 1 2 3 4 5 6 7 8 9 10
11 10 9 8 7 6 5 4 3 2 -1 0 +1 2 3 4 5 6 7
$P_{ti} - P$ 1000 LBS/IN²

PLOT IV